

Mucool Test Area Cryo-system Design

MICE/Mucool Meeting at LBL
October 22th 2002

Status at Fermilab/ Beams Division/Cryogenic department
by Ch. Darve, B. Norris, A. Martinez, L. Pei

(Presented by Edgar Black)



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Part IV – A look at the Windows and Absorber Vessel

Overview of the need for Liquid Hydrogen

Main requirements for the cryo-system:

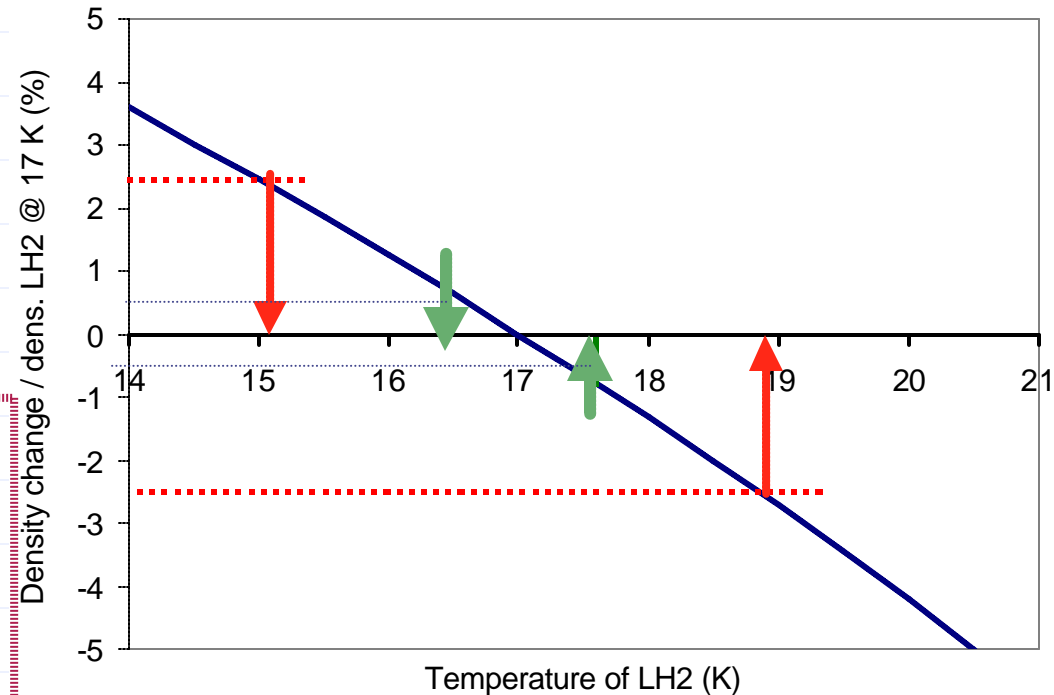
- ✓ Density fluctuation in the LH2 should be smaller than $\pm 2.5\%$
- ✓ $P = 1.2 \text{ atm} = 17.6 \text{ psia} = 0.12 \text{ MPa}$
- ✓ Subcool temperature $\Rightarrow 17 \text{ K}$



1- Stay below boiling point

2- Temperature difference $< 1 \text{ K}$
(using a large safety factor)

- in absorber volume
- in the cryo-system



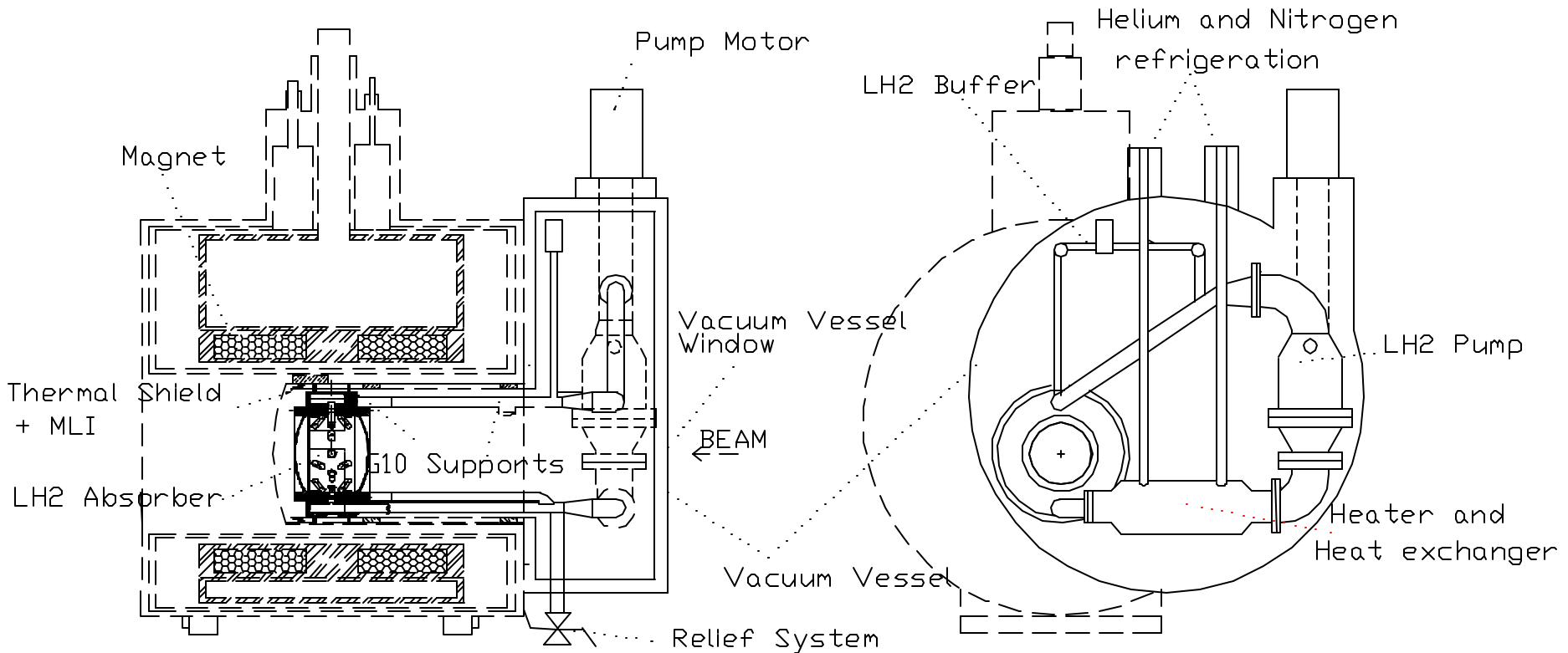


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Part IV – A look at the Windows and Absorber Vessel

Overview of MuCool Test Area cryo-system - cryostat



Ch. Darve/ Fermilab/ Beams Division/ Cryogenic Department
03/21/02



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Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

The **LH₂ pump** was designed and built by Caltech as a spare pump for the SAMPLE experiment (½ dia. of the pump used in E158)

Purpose:

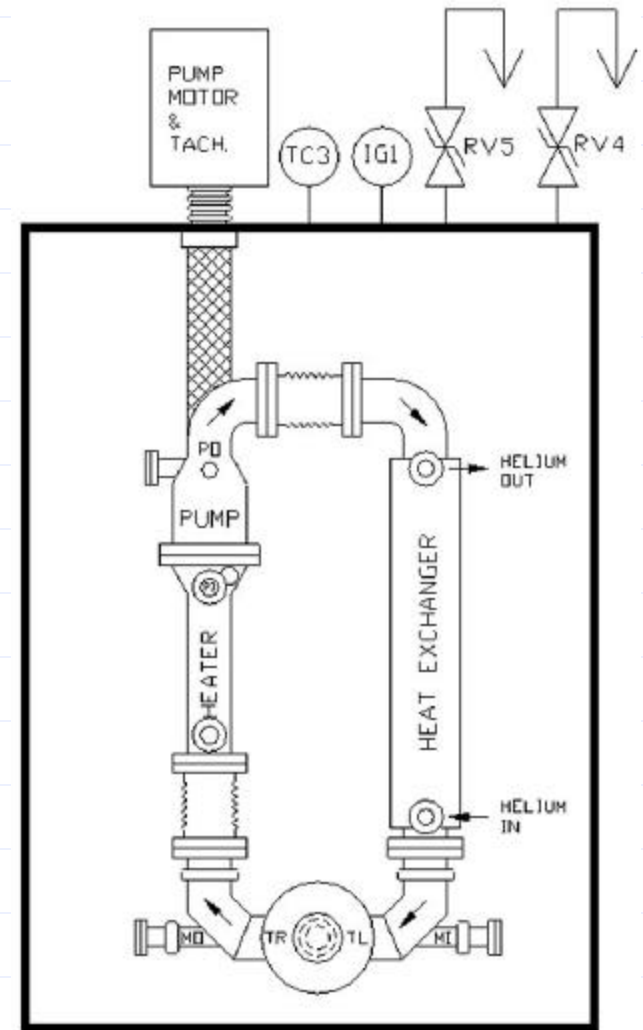
To circulate LH₂ in a close loop and provide force flow to remove the energy loss from the LH₂ absorber, with $\Delta T < 1$ K

Schematic of SAMPLE

Max. available flow at 17 K, 1.2 atm = 450 g/s

Reference:

"E.J. Beise et al., A high power liquid hydrogen target for parity violation experiments, [Research instruments & methods in physics research](#) (1996), 383-391"





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Overview on the Absorber Pump flow method

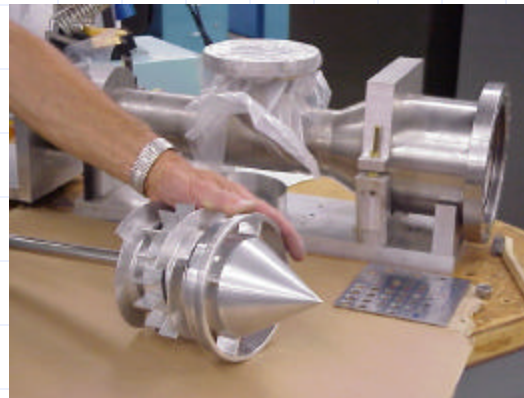
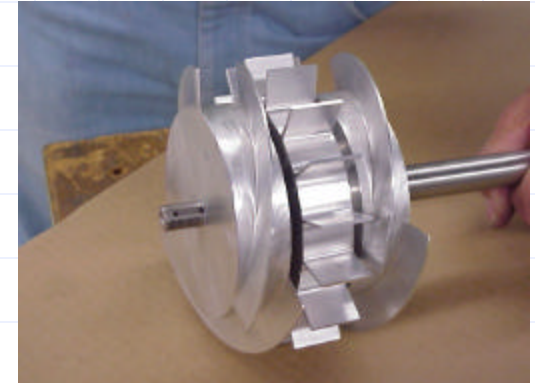
The LH₂ pump is composed of:

- ⇒ two impeller blades => to straighten the flow
- ⇒ three stators => to accelerate the flow
- ⇒ two cones => to reduce the impedance of the flow

Materials:

Impellers: Aluminum 6061 T6

Housing: 304



A motor located at room temperature drive the pump:
⇒ typical Tevatron Wet Engine 2 HP motor will be used



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Overview on the Absorber Pump flow method

❖ What is the mass flow needed to cool the beam?

Simulation of the flow by Wing Lau/ Charles H. Holding (Oxford) using Algor 2 D model

❖ How to use the results?

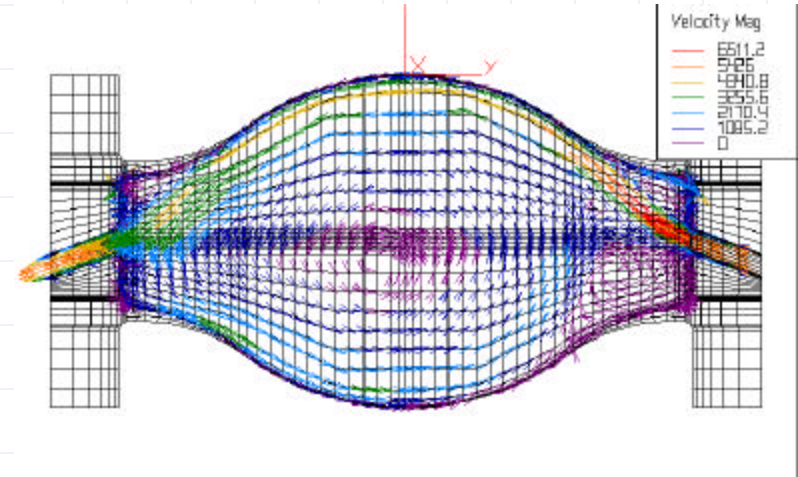
Determine velocity so that $\Delta T < 1K$

Step: 1/1

ΔT



Temperature



We determine the velocity, V , for the addoc temperature difference, DT :

$\Rightarrow m$ (for given DT , nozzle geometry and LH_2 prop.)

$\Rightarrow DP$ (for LH_2 cryoloop)

SEE WING LAU TALK

We do need to understand the thermo-hydraulic behavior of the LH2 absorber

◆ Example: Case of the maximum available flow by the LH2 pump

In order to be functional the LH2 absorber would need to be optimized (goal: reduction of the pressure drop)

Proposed changed: If $V=4$ m/s then $m=450$ g/s

Current geometry

LH2 abs:

Nozzle dia. = 0.6"

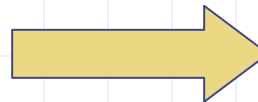
8 Supply nozzles

12 returns nozzles

Piping in the magnet bore:

40 cm long IPS 1" pipes

10 cm long IPS 2" pipe



Requested geometry

LH2 abs:

Nozzle dia. = 0.43"

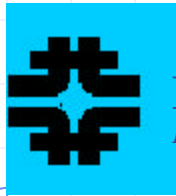
11 Supply nozzles

15 returns nozzles

Piping in the magnet bore:

20 cm long IPS 1" pipes

30 cm long IPS 2" pipe

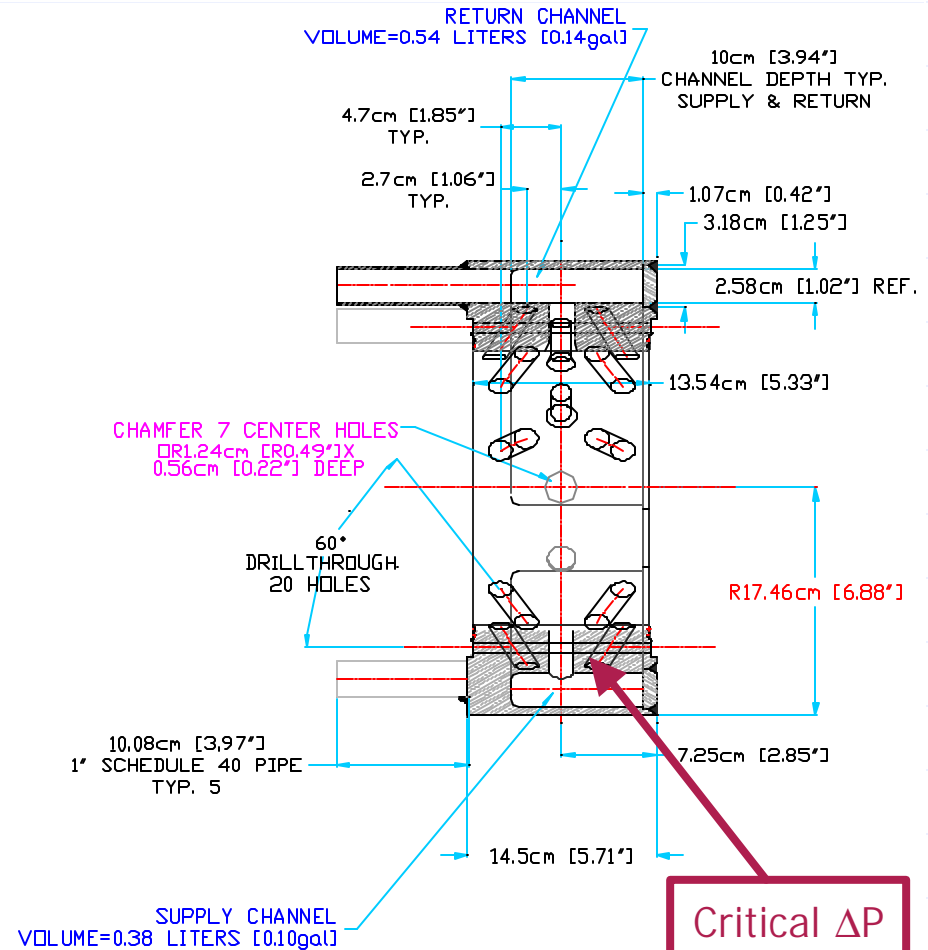
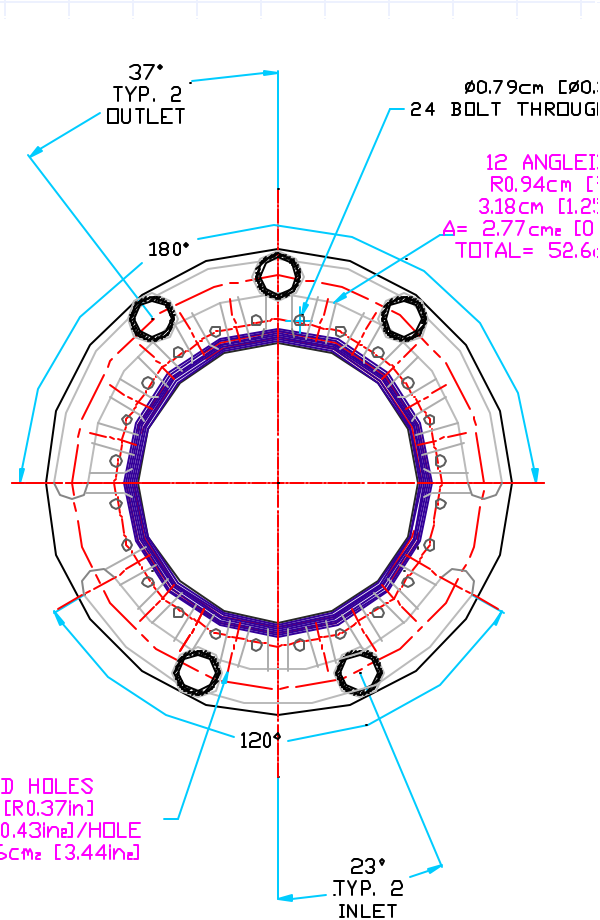


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LH2 Manifold absorber (by E. Black)



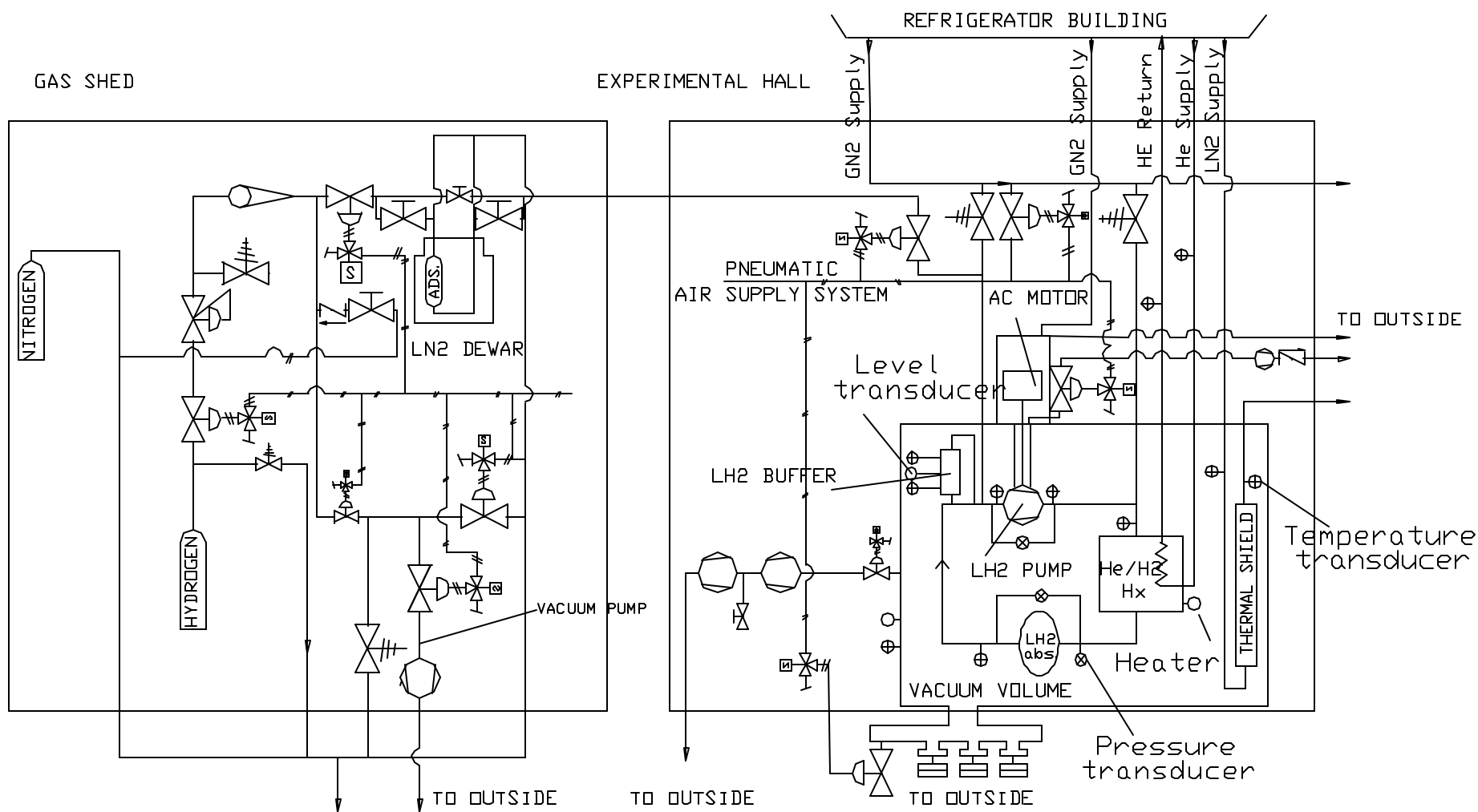


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Part V – A look at the Hydrogen Proposal

Process and Instrumentation Diagram





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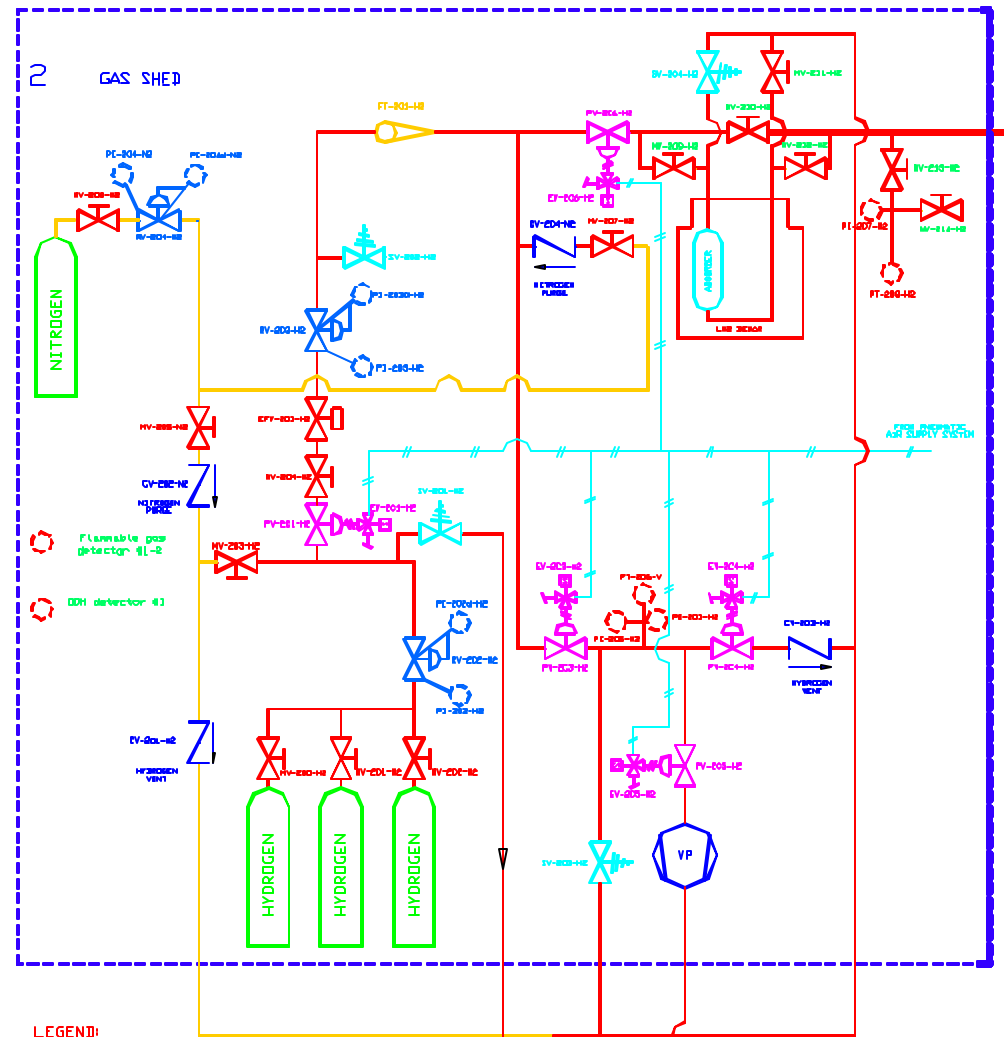
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Equipment:

- ◆ Gas H2 bottle
- ◆ Gas N2 bottle
- ◆ O2 adsorber
- ◆ Vacuum pump
- ◆ Flam. Gas detector
- ◆ ODH detector
- ◆ Pneumatic air supply sys.

Instrumentation:

- ◆ Flowmeter Transducer
- ◆ Pressure Reg. Valve
- ◆ Safety Valve
- ◆ Manual Valve
- ◆ Excess flow Valve
- ◆ Pneumatic Valve
- ◆ Electrical Valve
- ◆ Check Valve
- ◆ Pressure Indicator
- ◆ Pressure Transducer



LEGEND:
 DPI: Differential Pressure Indicator
 DPT: Differential Pressure Transducer
 EFV: Excess Flow Valve
 EV: Electrical Valve
 FI: Flow Indicator
 FT: Flow Transducer
 IT: Intensity Transducer
 MV: Manual Valve
 PI: Pressure Indicator
 PRV: Pressure Regulating Valve
 PT: Pressure Transducer
 PV: Pneumatic Valve
 TCV: Temperature Controlled Valve
 TT: Temperature Transducer
 SV: Safety Valve

NOTES:
 1 - ALL SYMBOLS CONFORM
 TO ANSI/ISA S5.1-1984(R1992)
 STANDARDS UNLESS OTHERWISE SPECIFIED.

FRONT



- ◆ Roughing Vacuum pump
- ◆ Turbo Molecular pump
- ◆ Gas He Supply/Return
- ◆ Gas N2 Supply/Return
- ◆ Liq. N2 Supply/Return
- ◆ Vaporizer
- ◆ Flam. Gas detector
- ◆ ODH detector
- ◆ Pneumatic air supply sys.

- ◆ Temperature Transducer
- ◆ Pres. Transducer and Indicator
- ◆ Flowmeter Indicator
- ◆ Heater
- ◆ Safety Valve
- ◆ Temperature Controlled Valve
- ◆ Pressure Reg. Valve
- ◆ Manual Valve
- ◆ Electro+ Pneumatic Valve
- ◆ Check Valve





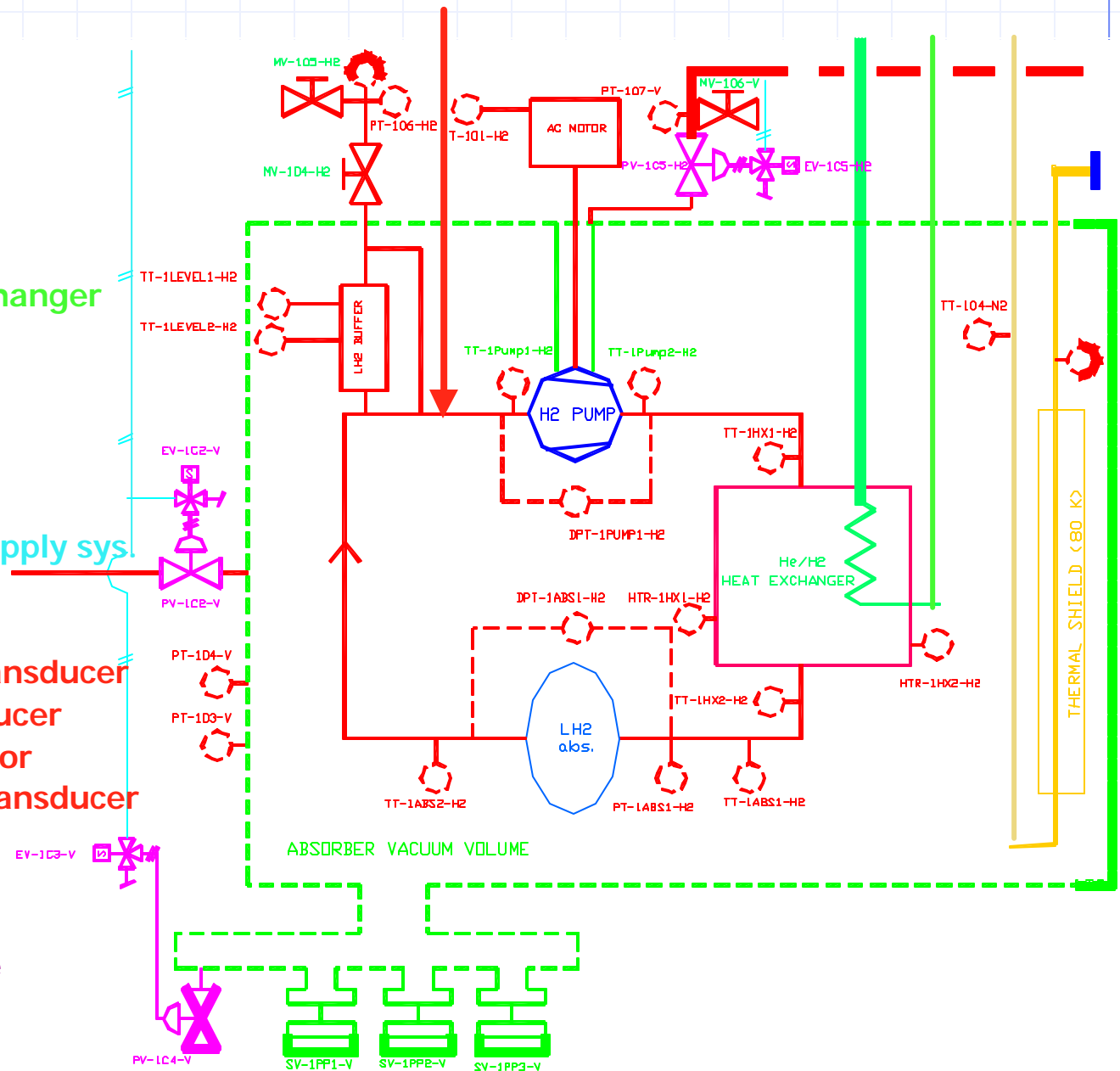
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Equipment:

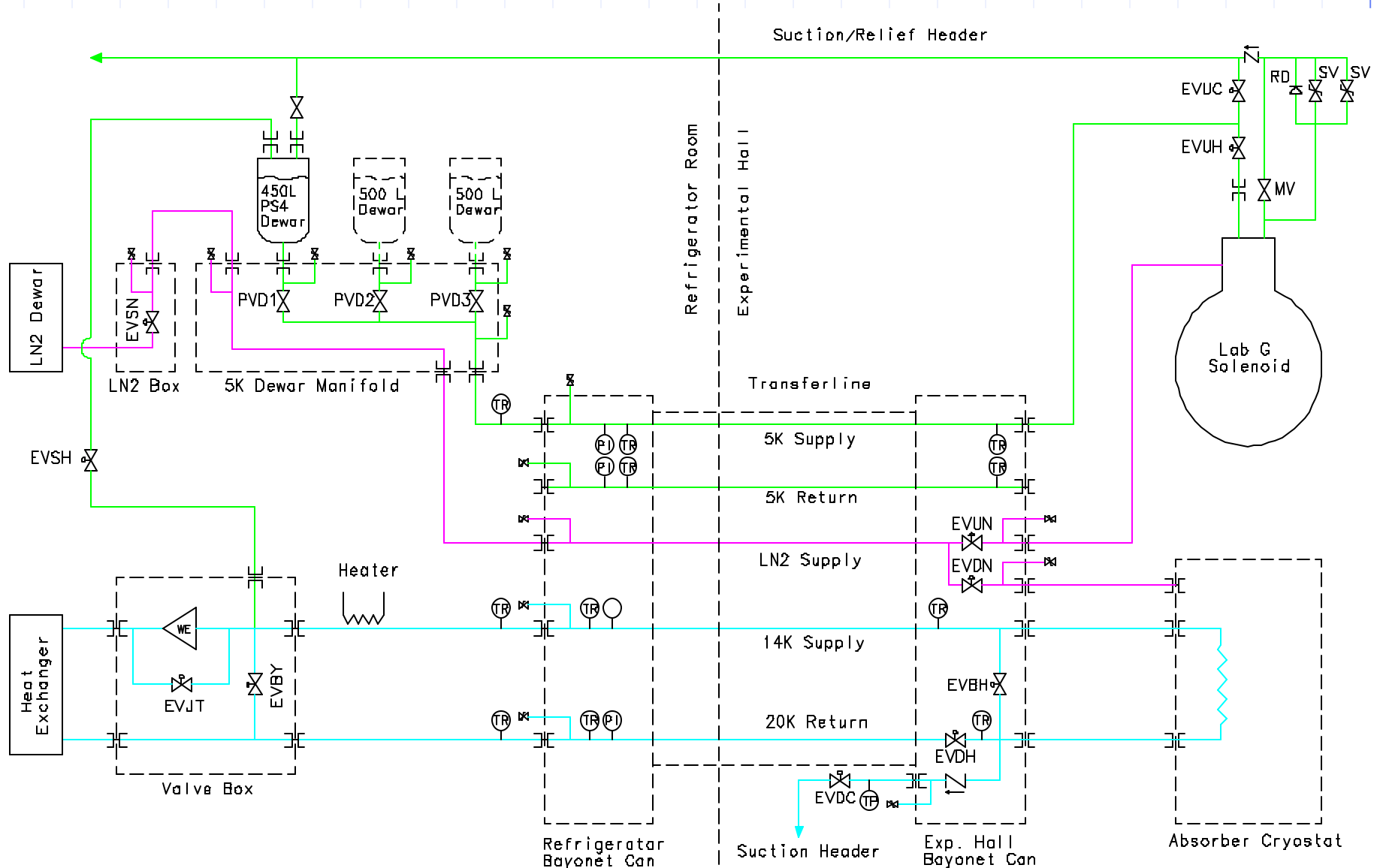
- ◆ Absorber
- ◆ He/H₂ Heat Exchanger
- ◆ LH₂ pump
- ◆ AC motor
- ◆ LH₂ buffer
- ◆ Vacuum pump
- ◆ Thermal shield
- ◆ Pneumatic air supply sys.

Instrumentation:

- ◆ Temperature Transducer
- ◆ Pressure Transducer
- ◆ Pressure Indicator
- ◆ Diff. Pressure Transducer
- ◆ Heater
- ◆ Safety Valve
- ◆ Manual Valve
- ◆ Pneumatic Valve
- ◆ Electrical Valve
- ◆ Check Valve



MuCool Helium Flow/Equipment Schematic



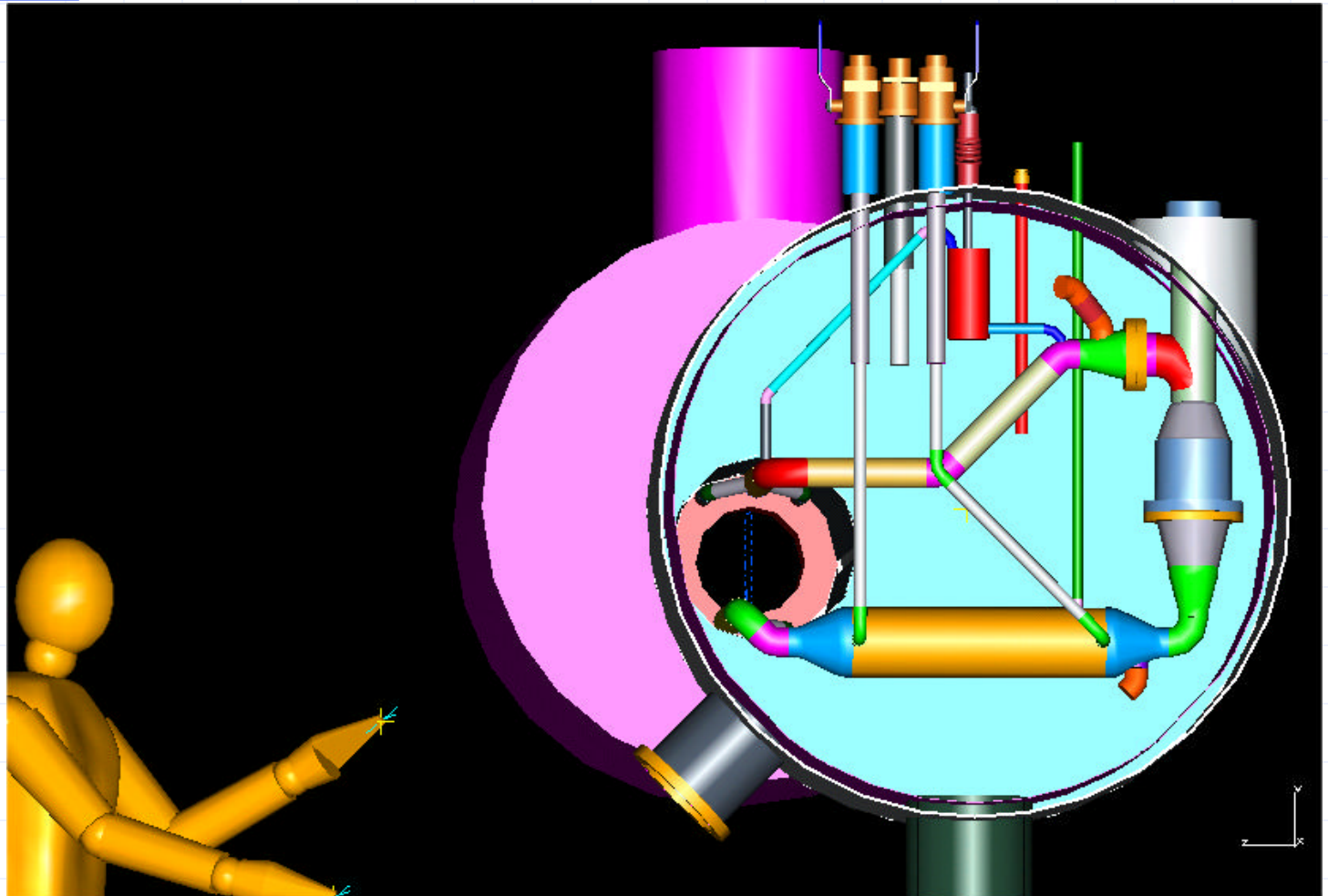


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Cryo-system design



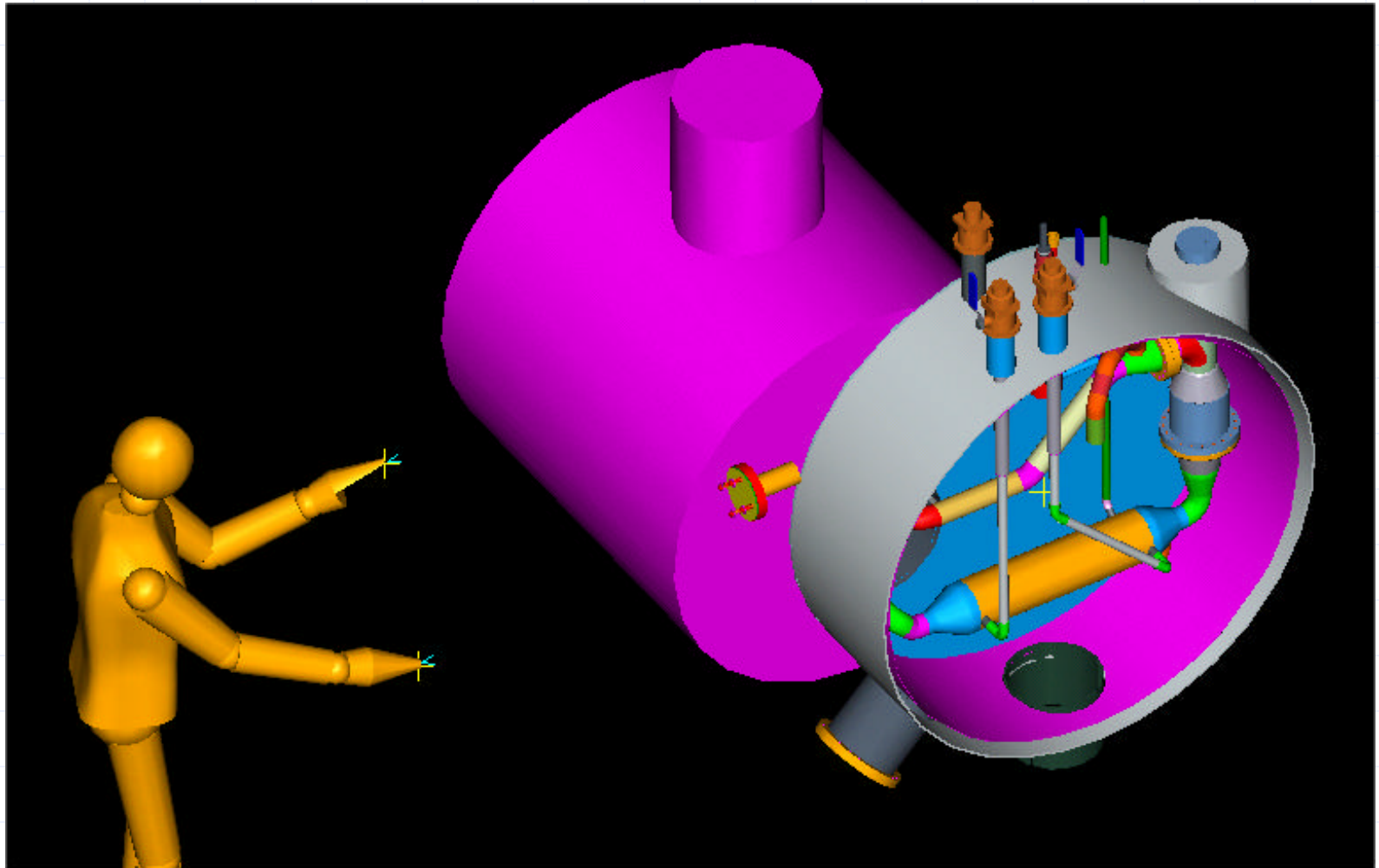


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Cryo-system design





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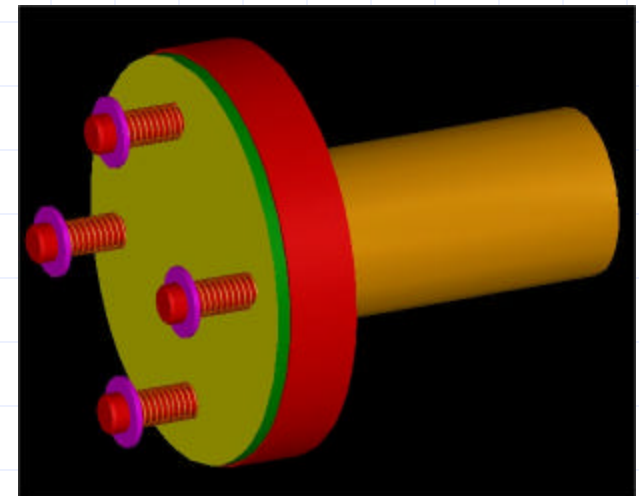
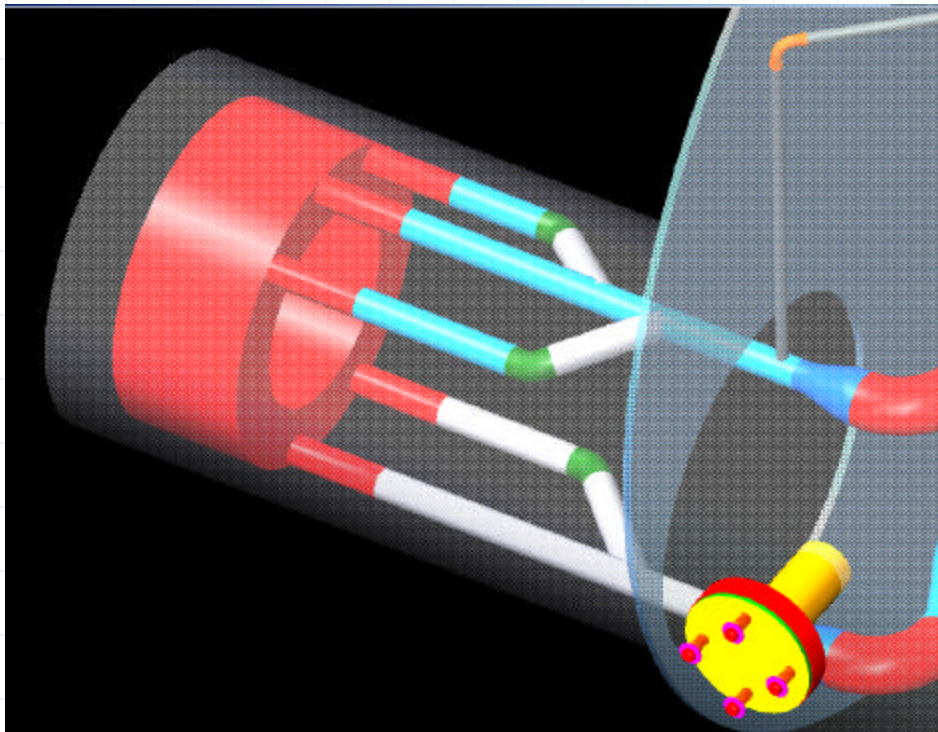
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Cryo-system design

1 - Cryostat Set-up assembly:

- Piping IPS1, IPS2 Sc5, Bimetallic transitions...
- Safety devices: Parallel plate, AGCO





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Part V – A look at the Hydrogen Proposal

Cryo-system design

1 - Cryostat Set-up assembly:

- Thermal + MLI,
- Vacuum vessel,
- Connection to pumping sys,
- Transfer lines and bayonets.





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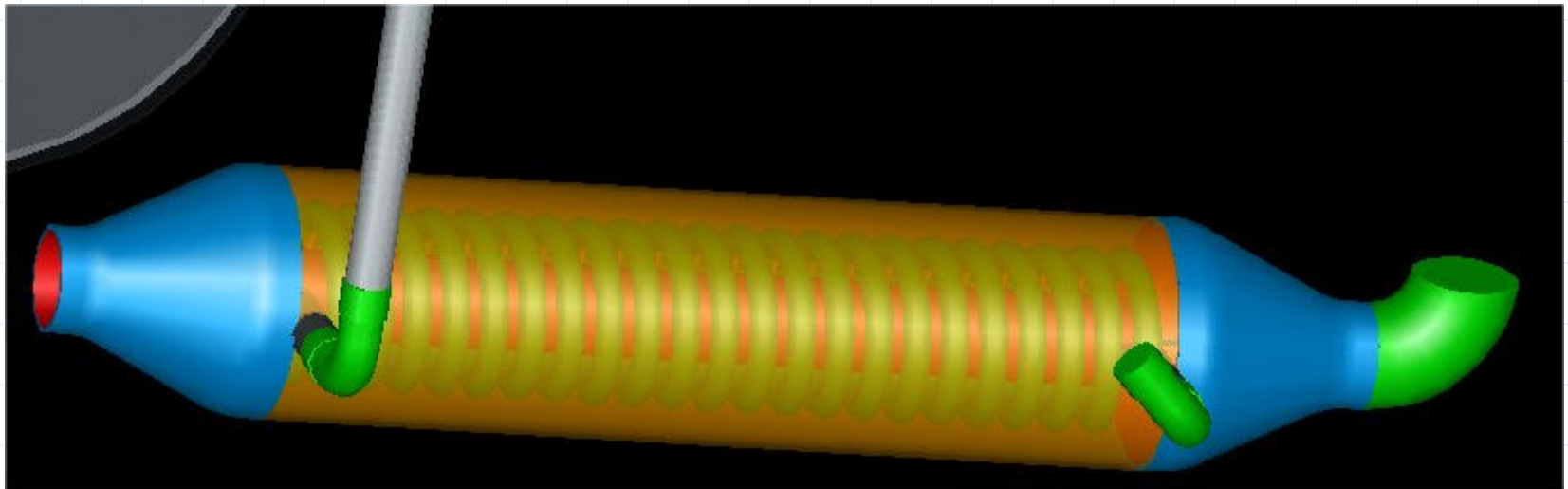
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Cryo-system design

2- Heat exchanger assembly:

- Copper coil,
- Outer shell,
- Diameter reduction,
- He inlet and outlet,





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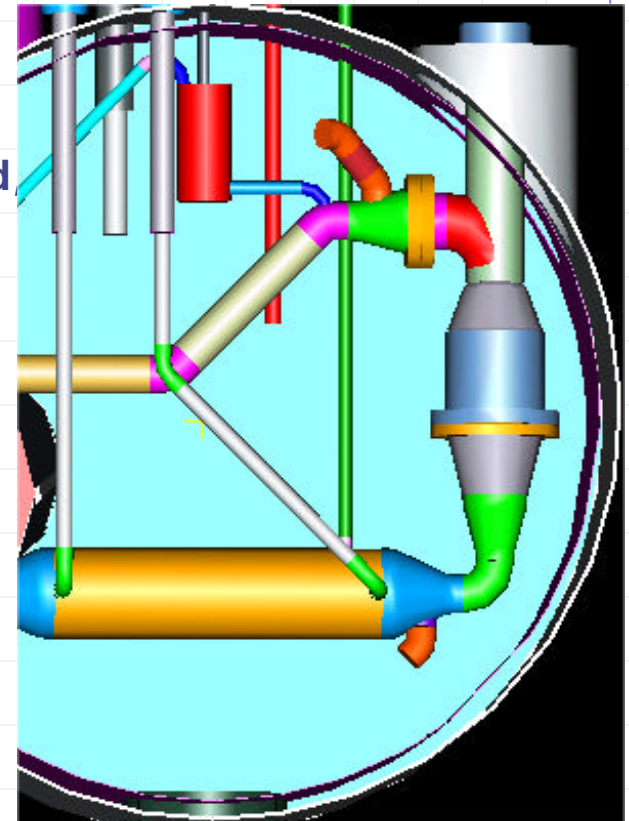
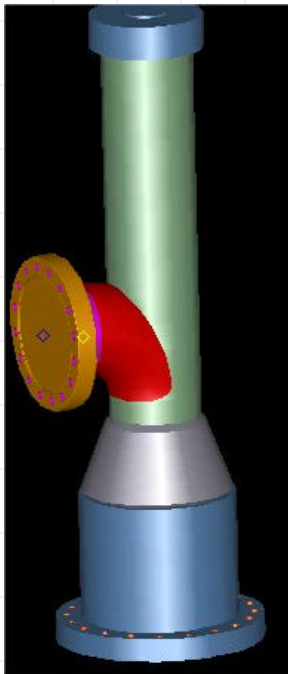
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Cryo-system design

3- LH2 Pump assembly:

- Pump torque transition,
- Motor outer shield,
- Cooling system,
- Pumping system of the outer shield
- Relief valves piping.





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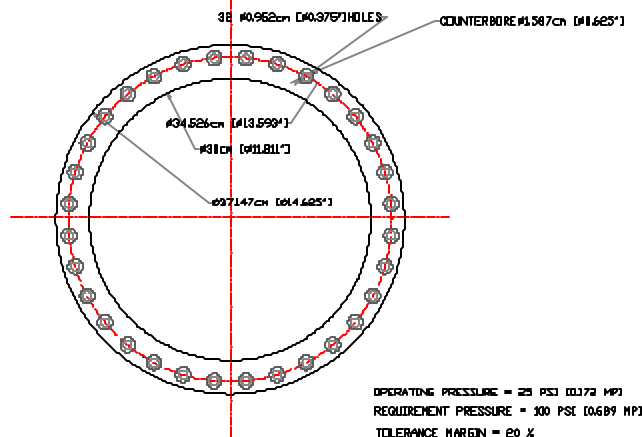
Cryo-system design

4- Absorber assembly:

Implement Ed Black/Wing Lau drawings with cryostat vacuum vessel windows, absorber

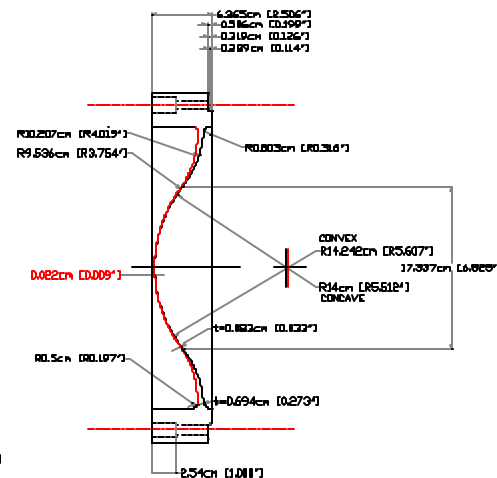
Design interface of the systems (flanges, piping)

- Absorber manifolds
- Windows in the loop
- Doubled-seal



ABSORBER VESSEL/WINDOWS
GEOMETRY PROFILE

Edgar Black/Wing Lau
04/7/2008



MATERIAL: 6061-T6 ALUMINUM ALLOY

thin/ind03ocnomp



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Part IV – A look at the Windows and Absorber Vessel

Overview on the Absorber Pump flow method

Status:

- **In order to design the total cryo-system, we do need to simulate the optimal flow regime (Oxford/cryo dpt).**
- **Focus:**
 - **Thermo-hydraulic behavior of LH2 absorber for which $DT_{max}=1\text{ K}$ (and 3 K): DT, DP , mass flow, power distribution**
 - **Influence of the beam distribution (volume-surface distribution)**
- ◆ **Upgrades from the Algor model:**
 - **Geometry upgrade, temperature upgrade**
 - **Influence of the nozzle number to reduce the hot spot=>3D model**

References:

http://www-bdnew.fnal.gov/cryo-darve/mu_cool/mu_cool_HP.htm

ICEC19 article - Cryogenic design for a liquid hydrogen absorber system